RESEARCH REPORT

SOUTHWESTERN FOREST AND RANGE EXPERIMENT STATION[1]
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TIMBER MANAGEMENT IN THE FORT VALLEY EXPERIMENTAL FOREST

WING MOUNTAIN UNIT

by

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NOTICE

The attached report inaugurates a new series of informal releases by this Station to be known as "Research Reports," which will include preliminary, progress, and in certain cases final reports of research information and results, of a character and scope that on the one hand may not meet the requirements of the more formal type of material suitable for publication by the Department or cooperating agencies, and on the other hand, cannot be condensed to within a maximum of 6 pages, the limit of our Research Notes series.

Southwestern Forest & Range Experiment Station

CONTENTS

TIMBER MANAGEMENT IN THE FORT VALLEY EXPERIMENTAL FOREST

WING MOUNTAIN UNIT

General Information

Area and location.

The Wing Mountain Unit of the Fort Valley Experimental Forest, also designated Sample Plot S3, contains 480 acres and lies within the boundaries of the Kaibab National Forest. It is located 6 miles west of the Fort Valley Experiment Station headquarters and 15 miles northwest of Flagstaff, Arizona.

Composition and age classes.

Ponderosa pine is the sole timber species. The overstory consists of three broad age classes--"yellow pine," mainly over 200 years; "intermediate," 150-200 years; "blackjack," mostly 140 to 150 years. There are few trees between the blackjack stage and the reproduction stage.

Site quality.

Site 2 for the Colorado Plateau. As to volume and height of mature dominants, the original stand was fairly typical of the Flagstaff region. Before cutting, 6-log trees were rather common and heights ranged up to 120 feet. All of the tallest trees were removed in the first cut, leaving the maximum between 90 and 100 feet. The altitude is between 7,400 and 7,600 feet. Precipitation averages close to 23 inches. The soil is of volcanic origin, a gravelly clay loam underlain by clay, generally from 2 to 3 feet deep, stony but fertile, as indicated by a luxuriant cover of bunchgrass which attains a height of 24 to 30 inches.

Logging.

The first cutting was in 1909 by the then prevailing Forest Service group selection method. In 1939 there was a second cut by three methods which will be described later.

Sample plots.

A sample plot was established directly after the 1909 logging was finished. The entire stand above 3.5 inches d.b.h. was measured for diameter. Two 12-acre plots within the area were tagged and diameters and heights were recorded individually for each tree; on the remainder of the area the trees were merely tallied by diameter classes and no heights were measured. Trees on the 12-acre

plots were also classified as to age, crown, and general condition. The two smaller units covered by the more detailed records were called "intensive" plots (S3-A and S3-B), and the remaining area an "extensive" plot (S3). Remeasurements were made at 5-year intervals. In 1924 all the trees on the extensive plot were tagged, and since then the diameters have been recorded individually but heights have not been measured.

Stand Before and After the First Cutting.

Of an original volume of approximately 9,600 board feet per acre, the first cut removed 63.3 percent, leaving 3,521 feet per acre. In the remaining stand, 40 percent of the volume was in mature classes (yellow pine) but the immature classes (blackjack and intermediate) made up 93 percent of the number of trees.

From 1909 to 1939 the volume increased to 5,939 feet per acre. Table 1 and figure 1 show the changes in distribution of diameter classes during the 30 years after cutting in 1909 and preceding the second cutting in 1939. In general there was a progressive "stepping-up" from the lower classes to the higher. Because of a dearth of seedlings, saplings, and poles at the time of the first cutting, the lower diameter classes were not replenished but actually declined in numbers.

At least one-third of the land was unoccupied by trees of any size in the original stand, and the first cutting increased the proportion of unstocked area to more than half. Yellow pines, originally in groups, were more or less scattered after the first cut. Blackjack groups were disturbed but little in the first cutting; generally they were overstocked, with trees of uniform age ranging from 8 to 26 inches d.b.h. This grouping habit must be kept in mind in order to understand the behavior of the cutover stands.

Growth, 1909 to 1939.

The mean annual increment from 1909 to 1939, deducting mortality but not defect, was 81 board feet per acre. Figures 2 and 3 show a sharp rise in the rate of increment during the first decade after cutting, followed by a persistent decline through the remainder of the 30-year period. This relation is most pronounced in the periodic increment, figure 2, which records the current growth in each 5-year period, whereas the mean increment in figure 3 is an average from the beginning of the record to the end of each period. A logical explanation is that acceleration after cutting did not become fully effective until the second period and that growth fell off in the third because the increased growing space made available by the cutting was gradually taken up. This, however, would not account for an actual decline of increment. But it is known that an increasingly large proportion of the trees

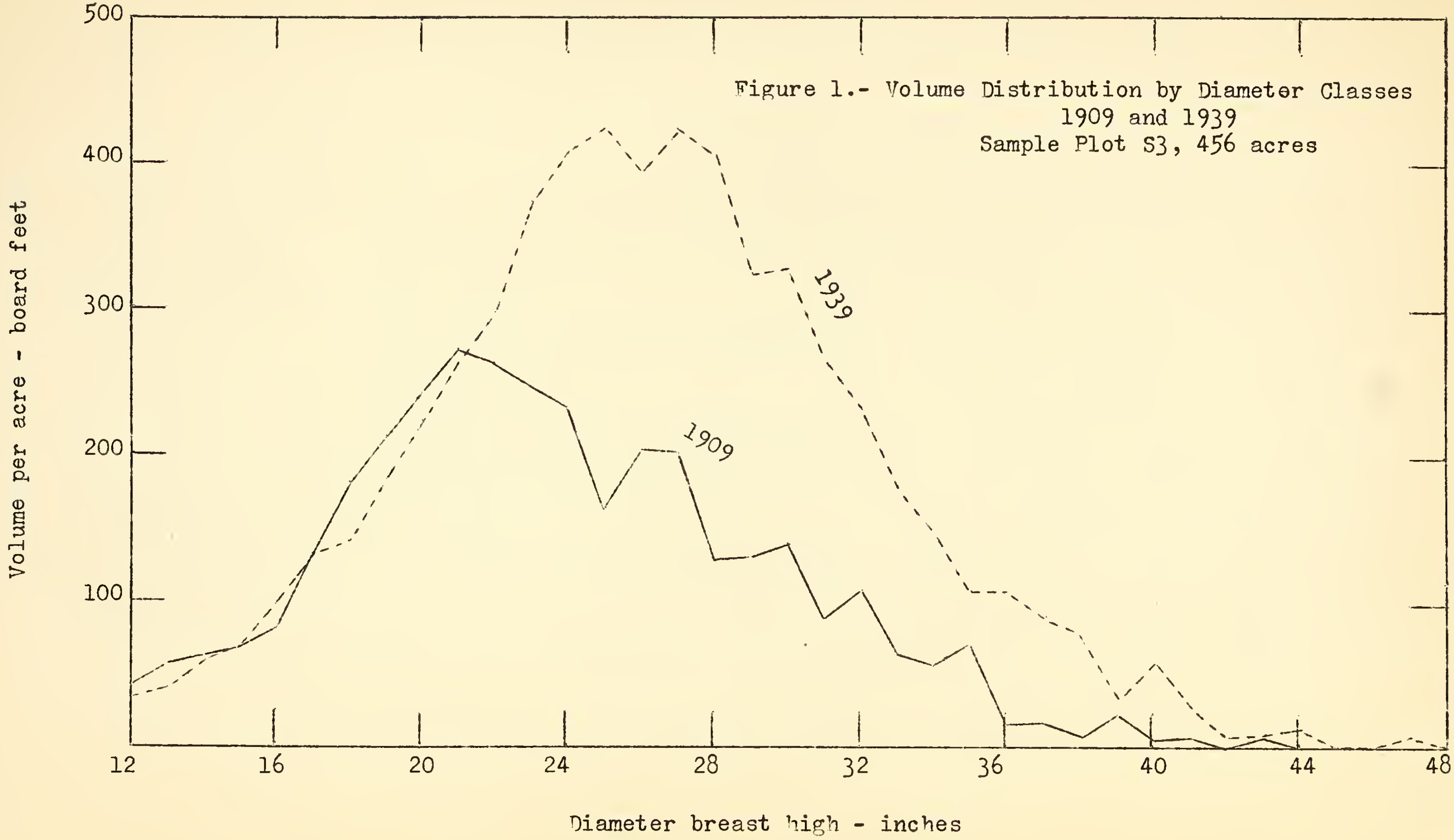
Figure 1.- Volume Distribution by Diameter Classes
1909 and 1939
Sample Plot S3, 456 acres
500
400
300
200
100
Volume per acre - board feet
12
16
20
24
28
32
36
40
44
48
Diameter breast high - inches
1939
1909

Table 1.- Number of trees and volume in board feet per acre by 3-inch diameter classes, 1909 and 1939. Sample Plot S3, 456 acres.

D.B.H. class	After 1909 cutting		1939 Before cutting		1939 Cut		1939 Left	
	No. trees	Vol. b.m.	No. trees	Vol. b.m.	No. trees	Vol. b.m.	No. trees	Vol. b.m.
Inches		Feet		Feet		Feet		Feet
6-8	2.48		2.35				2.35	
9-11	3.31		1.72				1.72	
12-14	2.81	162	2.18	128	0.57	35	1.61	93
15-17	2.20	283	2.31	297	0.71	93	1.60	204
18-20	2.69	633	2.29	544	0.87	207	1.42	337
21-23	2.00	778	2.33	929	0.92	367	1.41	562
24-26	1.01	596	2.07	1223	0.92	543	1.15	680
27-29	0.54	455	1.35	1148	0.67	576	0.68	572
30-32	0.29	334	0.71	821	0.43	500	0.28	321
33-35	0.13	197	0.28	427	0.21	315	0.07	112
36-38	0.02	42	0.15	272	0.10	202	0.05	70
39-41	0.02	35	0.05	118	0.05	108	0.00*	10
42-44	0.00*	6	0.01	25	0.01	18	0.00*	7
45-47			0.00*	7	0.00*	7		
Totals	17.50	3521	17.80	5939	5.46	2971	12.34	2968

*Less than 0.005 tree per acre

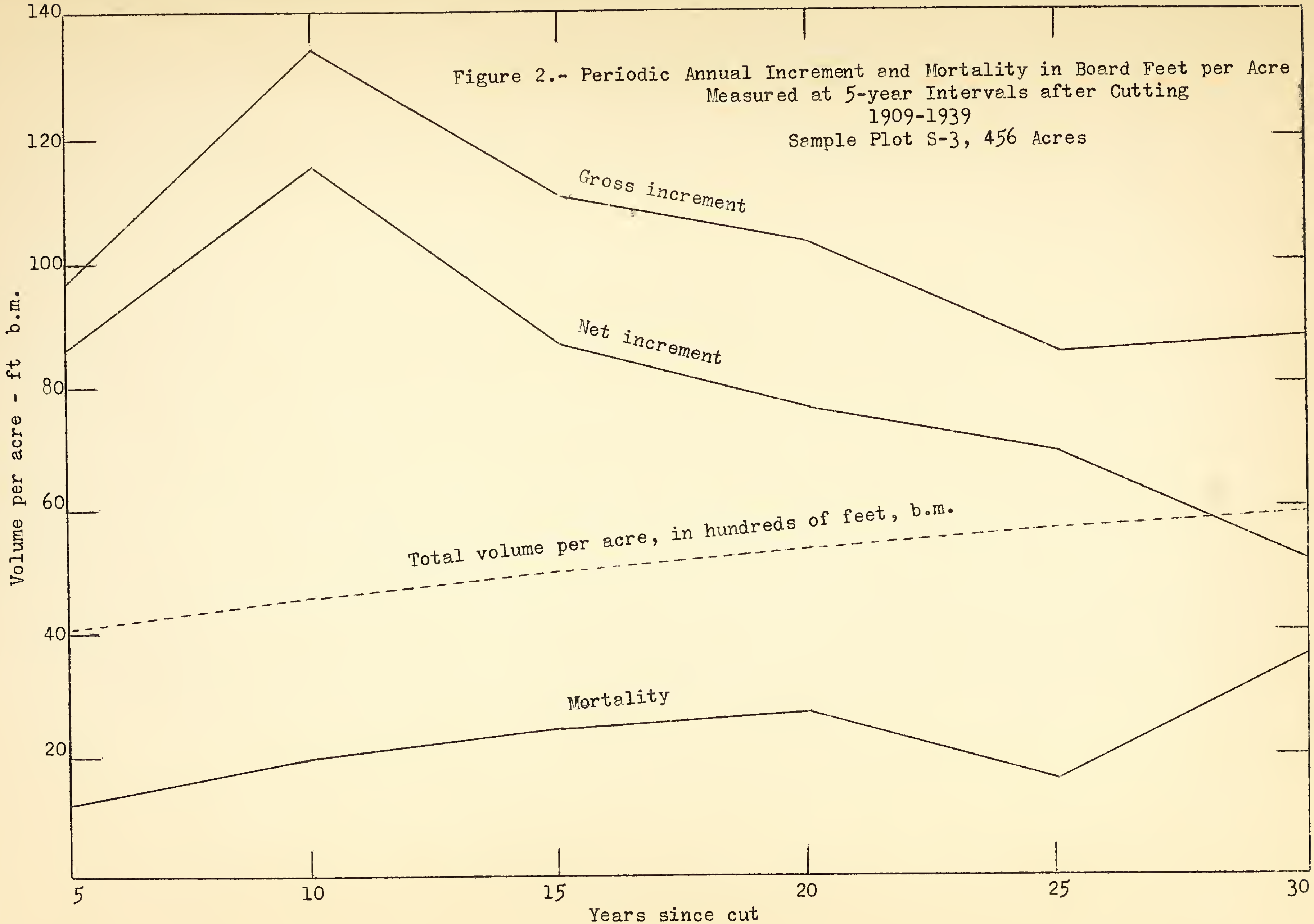

Figure 2.- Periodic Annual Increment and Mortality in Board Feet per Acre
Measured at 5-year Intervals after Cutting
1909-1939
Sample Plot S-3, 456 Acres

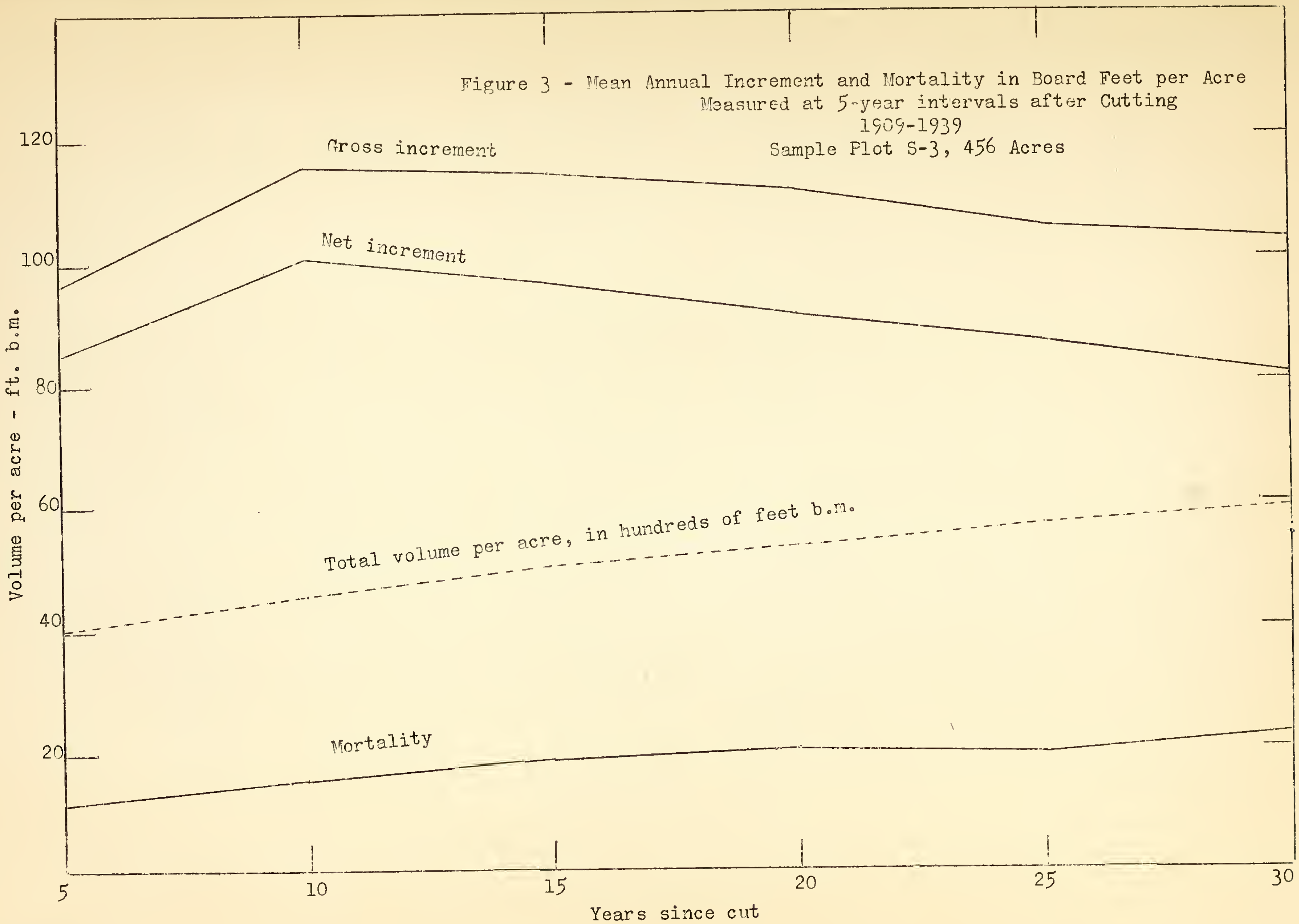

Figure 3 - Mean Annual Increment and Mortality in Board Feet per Acre
Measured at 5-year intervals after Cutting
1909-1939
Sample Plot S-3, 456 Acres

declined in vigor as a result of lightning injury and mistletoe. Another factor is precipitation. Annual precipitation at Fort Valley, averaged by 5-year periods (the period starting on November 1 prior to the first year and ending on October 31 of the fifth) as shown in table 2 follows in a general way the trend of periodic gross increment shown in figure 2.

Mistletoe, more perhaps than any other single factor, accounts for the decline in growth rate. Although the records are not adequate to provide a quantitative expression of mistletoe infection, observations have indicated a great increase not so much in number of mistletoe trees as in the intensity of infection. In 1939, 55.9 percent of all trees over 6 inches d.b.h. on the entire 480 acres were recorded as bearing more or less mistletoe. By degrees of infection, 22.7 percent of all the trees were classed as "light," 12.8 percent "moderate" and 20.4 percent "heavy." Table 3 gives an indication of the effect of mistletoe on growth during 30 years on the intensive plots S3-A and S3-B. With few exceptions, the decline of increment with increasing stages of infection is marked. Notable exceptions, which have not been explained, occur in the 21- and 26-inch classes. Occasionally, trees whose crowns are literally full of mistletoe are found to be growing rapidly, but they decline sooner or later.

Other biological agents that injure trees are the porcupine and the Abert squirrel. Porcupines are now well under control, but squirrels appear to be on the increase. In the course of the 1939 measurements 7.8 percent of all trees on this plot were recorded as showing distinct evidence of squirrel activity and 3.7 percent were classed as seriously injured. The squirrel cuts off growing twigs to the extent of causing near defoliation in extreme cases. He also eats immature cones and cuts off seedlings near the ground line.

Considering both gross and net increment, the stand was a much less efficient wood-producing plant during the last 15 years than during the first 15 years. This relation becomes all the more significant when it is taken into account that the volume of growing stock increased 70 percent during the 30-year period. Periodic net annual increment declined from 115 board feet per acre in the second 5-year period to 53 in the sixth.

Mortality, 1909 to 1939.

Mortality assumes a general upward trend (figures 2 and 3), the only exception being in the fifth period when windfall was unusually light. Periodic annual mortality increased from 11 board feet in the first 5-year period to 36 in the last.

According to table 4, the three main agents responsible for the death of trees are, in order of magnitude, mistletoe, wind, and lightning. During the 30 years, mistletoe was responsible for

Table 2.- Precipitation in inches by growth periods, Fort Valley Forest Station, 1909-1939.

Year[1]	Nov. 1 to Mar. 31		Apr. 1 to Oct. 31		Nov. 1 to Oct. 31	
	Current	Average 5 years	Current	Average 5 years	Current	Average 5 years
1910	11.00		7.28		18.28	
1911	9.97		15.06		25.03	
1912	6.60		11.70		18.30	
1913	6.92		9 98		16.90	
1914	6.98	8.29	11.96	11.20	18.94	19.49
1915	9.32		11.27		20.59	
1916	17.88		13.72		31.60	
1917	6.14		13.19		19.33	
1918	9.33		10.42		19.75	
1919	8.62	10.26	21.86	14.09	30.48	24.35
1920	16.92		10.54		27.46	
1921	6.65		17.72		24.37	
1922	14.58		10.80		25.38	
1923	11.75		12.80		24.55	
1924	10.06	11.99	10.78	12.53	20.84	24.52
1925	8.11		14.45		22.56	
1926	5.94		11.59		17.53	
1927	13.48		15.89		29.37	
1928	6.63		13.04		19.67	
1929	12.18	9.27	16.21	14.24	28.39	23.50
1930	8.36		14.35		22.71	
1931	6.39		15.11		21.50	
1932	15.03		11.61		26.64	
1933	6.47		13.93		20.40	
1934	4.89	8.23	13.03	13.61	17.92	21.83
1935	12.88		11.97		24.85	
1936	9.65		17.19		26.84	
1937	16.76		11.96		28.72	
1938	14.28		9.90		24.18	
1939	9.61	12.64	9.96	12.20	19.57	24.83
(Mean (1910-39	10.11		12.98		23.09	

[1] Year in which period ends.

Table 3.- Number and increment of mistletoe-infected trees on Sample Plots S3-A and S3-B, 24 acres, 1909-39.

(Volumes uncurved)

D.B.H. class 1909	Total number 1939	Degrees of infection: None: Number	None: Percent	Light to medium: Number	Light to medium: Percent	Heavy: Number	Heavy: Percent	Average increment per tree by degrees of infection: None	Light to medium	Heavy
								Ft.bm	Ft.bm	Ft.bm
12	34	15	44.1	11	32.4	8	23.5	85	81	66
13	45	25	55.6	11	24.4	9	20.0	136	114	79
14	44	25	56.8	11	25.0	8	18.2	153	142	111
15	25	12	48.0	9	36.0	4	16.0	170	217	66
16	20	12	60.0	3	15.0	5	25.0	198	150	83
17	22	9	40.9	8	36.4	5	22.7	199	200	104
18	21	9	42.9	7	33.3	5	23.8	212	174	162
19	36	16	44.5	13	36.1	7	19.4	251	242	169
20	26	14	53.9	5	19.2	7	26.9	228	245	155
21	23	9	39.1	10	43.5	4	17.4	202	259	292
22	19	5	26.3	11	57.9	3	15.8	331	285	179
23	14	2	14.3	8	57.1	4	28.6	215	285	173
24	12	7	58.3	2	16.7	3	25.0	298	402	186
25	8	6	75.0	1	12.5	1	12.5	318	240	185
26	4	2	50.0	1	25.0	1	25.0	231	287	292
27	3	2	66.7	1	33.3			364	501	
28	2	1	50.0	1	50.0			402	264	
29	1			1	100.0				523	
30	2	1	50.0	1	50.0			354	288	
31	6	4	66.7	2	33.3			477	344	
32	2	2	100.0					474		
Total	369	178	48.2	117	31.7	74	20.1			

Table 4.- Mortality by causes. Percent of number and volume b.m., killed by different agencies, 1909-1939, Sample Plots S3, S3-A, and S3-B, 480 acres.

D B H. class	Mistletoe		Wind		Lightning		Insects		Unclassified	
	No. trees	Volume b.m.	No. trees	Volume b.m.	No. trees	Volume b.m.	No. trees	Volume b.m.	No. trees	Volume b.m.
Inches	%	%	%	%	%	%	%	%	%	%
12 - 20	7.1	6.5	1.6	1.8	0.7	1.0	0.8	0.8	1.2	1.3
21 - 30	4.5	5.8	3.7	4.5	3.4	4.0	0.6	0.7	0.5	0.5
31+	10.8	11.1	15.2	14.9	13.9	14.8	1.3	1.2	0.6	0.6
12+	6.4	6.7	2.6	5.0	1.9	4.6	0.7	0.8	1.0	0.8
Percent of total dead										
	50.6	37.6	20.6	28.2	15.1	25.4	5.9	4.3	7.8	4.5

50.6 percent of the total loss in numbers and 37.6 percent of the loss in volume. It accounts for a loss of 6.7 percent of the original volume of the stand. Notwithstanding the effort to remove seriously infected trees in 1909, mistletoe was the most important cause of mortality even in the first 5-year period after logging. The high mortality in the last period is due mainly to increased activity of mistletoe. The apparently abnormal rise at the lower end of the mortality graph in figure 4 is due to mistletoe which is noticeably prevalent on suppressed and intermediate trees, no doubt accounting in large measure for their subordinate state.

Table 5 and figure 4 confirm the common observation that large trees are a poor risk. On another series of plots[1] the mortality in trees over 32 inches d.b.h. exceeded their increment during 20 years after cutting. Although it is not possible to make the same comparison for this area because individual tree records are available only for the last 15 years, incomplete records point to a similar relation. One qualification is that blackjacks are less vulnerable to both wind and lightning than are yellow pines of the same diameter.

Age and vigor classes.

In 1939, before the cutting, W. G. Thomson of the Region 3 Division of Timber Management classified all trees above 6 inches d.b.h. according to the Keen[2] system as modified in the Southwestern Region.[3] An additional vigor class designated AA was introduced in order to distinguish between normal, full-crowned trees and wolf trees.

Results of the classification are presented in table 6. Outstanding features are the small number of trees in age class 1 and the large numbers in classes 2C and 3C. On the basis of actual age, most of the trees in 1C and 1D would go in class 2C or 2D, although they are below 12 inches d.b.h.

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[1] Pearson, G. A. Growth and mortality of ponderosa pine in relation to size of trees and method of cutting. Jour. Forestry 38:323-327. 1940.

[2] Keen, F. P. Relative susceptibility of ponderosa pines to bark-beetle attack. Jour. Forestry 34:919-927. 1936.

[3] Thomson, W. G. A ponderosa pine growth rate classification. R-3 circular. Jan. 30, 1939.

Table 5.- Mortality in relation to tree diameter, 1909-1939, Sample Plots S3, S3-A, and S3-B, 480 acres.

D. B. H. class	Stand after 1909 cut				Mortality			
	Total		Per acre		30 Years		Annual	
	No. trees	Volume b. m.	No. trees	Volume b. m.	No. trees	Volume b. m.	No. trees	Volume b. m.
Inches		Feet		Feet		Feet	%	%
12 - 20	3,825	529,364	7.97	1,103	437	60,205	0.38	0.38
21 - 30	1,775	939,700	3.70	1,958	226	145,835	0.42	0.52
31+	158	230,926	0.33	481	66	98,070	1.39	1.42
12+	5,758	1,699,990	12.00	3,542	729	304,110	0.42	0.60

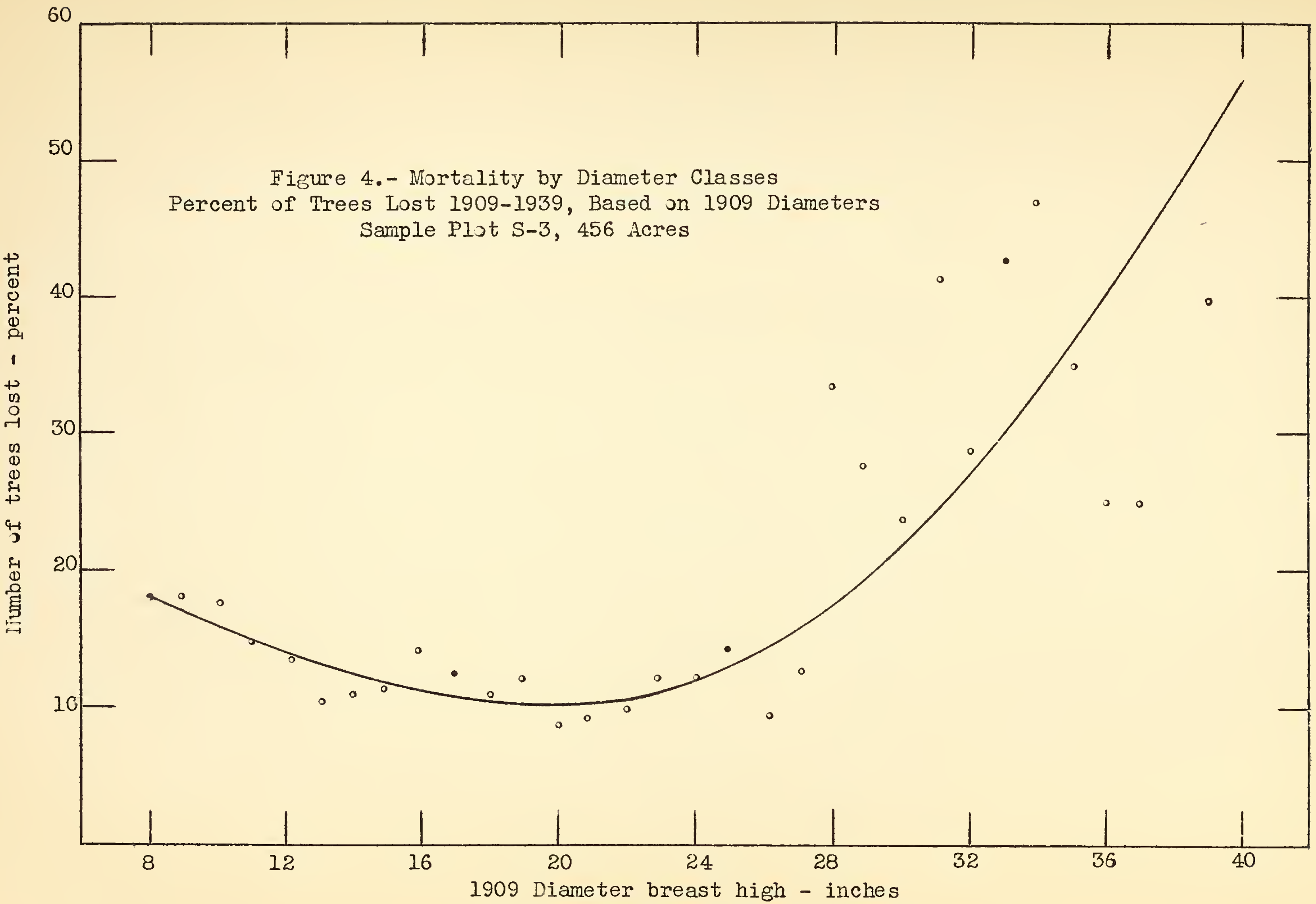

Figure 4.- Mortality by Diameter Classes
Percent of Trees Lost 1909-1939, Based on 1909 Diameters
Sample Plot S-3, 456 Acres

Table 6.- Classification of trees by age and crown development, immediately before 1939 cutting.*

Vigor classes, based on crown development	Age class				
	1 Young black-jack	2 Black-jack	3 Inter-mediate mature	4 Mature-overmature	Totals
	%	%	%	%	%
AA Very full crown (wolf trees)	0.02	2.43	1.89	0.14	4.48
A Full crown	0.40	7.10	6.68	1.66	15.84
B Medium crown	0.54	10.65	12.37	1.21	24.77
C Light crown	3.35	20.10	12.83	1.14	37.42
D Weak crown	4.81	7.24	4.81	0.63	17.49
Totals	9.12	47.52	38.58	4.78	100.00

*Classification by W. G. Thomson

Log grades.

Thomson also estimated the number of logs and their grades in the standing trees previous to logging in 1939. The classification used is a modification of the Pacific-Northwest system as modified for the Southwest in the Region 3 circular 29-S-1 of February 17, 1939. Foresters will be impressed by the almost total absence of grade 1 or "surface clear" logs, and the preponderance of grades 5 and 6 which are at the bottom of the scale of values. Clearly, one of the challenging problems in the Southwest is how to grow timber that will yield a higher percentage of logs in grades 1, 2, and 3, and a correspondingly lower percentage in grades 5 and 6.

Table 7.- Log grades as classified in standing trees before the 1939 cutting.

Log grades*	Number of logs	Percent of total number
1	86	0.49
2	387	2.20
3	1943	10.91
4	646	3.67
5	7849	44.54
6	6730	38.19
Total	17621	100.00

*As defined in R3-S, Sales Policy Utilization letter of February 17, 1939. Logs classified by W. G. Thomson, 1939.

Restocking.

Age classes below 100 years were almost nonexistent at the time of the first cutting in 1909. A plausible theory is that any seedlings which started during the century prior to 1909 were destroyed by fire. According to studies by Assistant Forest Pathologist Stuart R. Andrews, fire scars dating back to 1901 occur quite generally over the area. Grazing may also have been an important factor, beginning in the early 80's. In fact, grazing on the extensive plot is known to have virtually eliminated all seedlings which started between 1909 and 1919, especially a fair stand of 1914 germination. The two intensive plots S3-A and S3-B were fenced in the fall of 1910. By 1918 seedlings had become fairly numerous in spots, averaging about 50 per acre within the exclosures. Many of these were later killed or damaged by porcupines prior to about 1928 when control of this pest became effective.

Reproduction in 1909 was so abundant that, despite heavy damage by livestock and rodents, survival was adequate except in spots such as bed grounds and sites occupied by overluxuriant bunchgrass. Since only 10 to 15 percent of the area failed to restock, reproduction was considered generally satisfactory. Logging has increased the proportion of poorly stocked area to about 20 percent, and since log landings are virtually denuded, reproduction is again in order.

Whether the same factors that balked reproduction in these spots 20 years ago will do so again depends on various circumstances. Scarification of the soil by log skidding should retard bunchgrasses for several years. The area is now grazed only by sheep, which graze bunchgrasses sparingly. Slash has been scattered in the openings with a view toward discouraging their use as bed grounds. Sheep have browsed young seedlings much less in recent years than when the 1919 class was in the small seedling stage. Reliance must not be placed on this fact, however, because sheep are browsing larger seedlings intermingled with the small ones that are untouched. It is reasonable to believe that if the larger seedlings did not exist, the small ones would be browsed as they were in 1919 and following years when they constituted almost the only browse. Considerable numbers of 1919 and 1929 seedlings are still below 3 feet tall. When they grow beyond reach of sheep, small seedlings may again suffer. The sooner a new stand of seedlings can gain a foothold, the less grass competition will be encountered and the less will be the danger from sheep.

The Second Cutting

The volume before cutting in 1939, as determined by volume table, was 5,939 board feet per acre. Cutting removed 1,252,040 board feet, gross scale, on 468 acres, or 2,675 feet per acre, leaving 12 acres uncut. Defect amounted to 10.8 percent. The average volume left (by volume table) was 2,968 board feet per acre.

Cutting in 1939 followed three methods: (1) Favoring Dominants, (2) Favoring Subordinates, and (3) Salvage Cutting. In addition, the 12-acre plot S-B was left uncut.

Method 1 - Favoring Dominants.

The guiding principle is that dominants which are in condition to grow shall be favored over subordinates of slower growth. In practice, however, small subordinates were not generally removed unless they had diseased crowns or defective boles because it is recognized that they do not compete seriously with the dominants. Blackjack groups were disturbed but little. Yellow pines (Class 4) above 30 inches d.b.h. were cut unless needed for seed.

Method 2 - Favoring Subordinates.

This method is also called Improvement Selection.

Subordinates were favored over dominants wherever the subordinates had good boles and gave promise of growth when released. The theory is that many small, clean-boled trees will in the long run produce more and better lumber when released than will be produced by a few dominating, large, and limby trees. Short boles and deformed tops are not regarded as a serious handicap if the tree has the making of a good butt log. Yellow pines above 26 inches d.b.h. were cut unless needed for seed.

Method 3 - Salvage Cutting.

Only trees which might be expected to die during the next 30 years were cut. In this class were included lightning-struck and badly mistletoe-infected trees, also Class 4 trees over 34 inches d.b.h. unless needed for seed.

Comparison of the three methods.

In practical application, the difference between methods 1 and 2 proved to be less than anticipated. It happens that many of the large dominants in blackjack groups are subject to removal under either of the two methods, because they have been struck by lightning or because they are misshapen or mistletoe-infected. Some blackjack groups were cut heavily because of mistletoe, thus overshadowing any predetermined method of cutting. Yellow pine stands were marked heavily in the first cut. As a result of mistletoe control in both cuttings, it is common to find areas of several acres on which scarcely a tree above pole size now remains.

No conscious effort was made to use any tree classification as an arbitrary guide in marking although, to a large extent, a similar effect came about automatically. Injured and diseased trees usually fall into vigor class C or D and were cut under all methods, if merchantable; on the other hand, trees which fall into these classes because of crowding are usually below economic size, and were left in all three methods.

For a comparison of methods of cutting, it is desirable to start out with uniform stands. It was recognized from the beginning that, because of great irregularities of distribution, any attempt to obtain comparable stands, even by breaking the area into small subdivisions, would be difficult; and, further, that even if a series of comparable plots could be obtained on a basis of volume and distribution of diameter classes, variable cutting requirements imposed by mistletoe would upset the balance. The best comparison possible is in the response of individual trees and tree classes in blackjack groups, or the response of entire groups, as reflected in measurements before and after cutting. Far more can be learned from this kind of study than from empirical volume-per-acre comparisons.

With the foregoing in mind, the area was divided into three equal parts in the form of strips one-third mile wide, extending the whole length of the area in a north and south direction. The choice of a north-south rather than an east-west course of the strips was influenced by the fact that the only important drainage traverses the greater part of the area in an east-west direction; also a series of large bed grounds extends across the entire south side of the area. The three strips, each representing a method of cutting, are numbered from east to west, in the same order as the methods of cutting described above.

Table 8 shows the volumes cut and left on each division. The respective volumes in board feet per acre before the second cutting were: 1. Favoring Dominants 5,157, 2. Favoring Subordinates 6,518, and 3. Salvage 6,127. The corresponding volumes left were 2,211, 2,645, and 3,967. The percentages cut, in the same order, were 57.1, 59.4, and 35.3. Marking was guided solely by silvicultural principles outlined in the description of the three methods; no attention was paid to volume or percentage cut and left; in fact, these compilations were not made until after cutting was completed.

Logging Practice in 1939.

The sale and cutting of timber was administered by the Kaibab National Forest under immediate direction of Junior Forester William L. Chapel, who also scaled the logs.

Logging began September 8 and ended December 22, 1939. Employment averaged 15 men over a period of 3 months. All the laborers lived in Flagstaff or Bellemont, and drove to and from work daily.

The logs were skidded to landings with a tractor where they were loaded on the trucks with an improvised power loader. They were trucked to the A. L. & T. mill in Flagstaff, 15 miles distant.

The stumpage price was $3.57, including deposits of 5 cents per M for brush burning and $1 for stand betterment under the Knutson-Vandenberg Act.

Slash disposal was a modified form of lopping and scattering. In fact, there was little scattering but much attention was given to release of seedlings by the handling of brush.

Approximate cost figures furnished by the operator, C. C. Butler, are as follows:

	Per M
Felling, limbing, and bucking (contract)........	$1.00
Skidding (includes 10 cents for maintenance of equipment).................	1.20
Loading (includes 10 cents for maintenance of equipment).................	.90
Trucking (includes 20 cents for maintenance of equipment).................	2.45
Brush disposal and snag felling (contract)	.30
Total cost of logging and trucking	5.85
Stumpage	3.57
Cost of logs in the pond	$9.42

Slash disposal.

In most instances the trees were felled into stands of reproduction or near groups of trees where the brush could not be burned without excessive damage. For this reason, the limbs and tops were, as a rule, left in place except that they were moved or cut sufficiently to liberate seedlings and saplings. Following the slash disposal provided by the contractor, a man paid out of Knutson-Vandenberg funds covered the area systematically, releasing seedlings bent down by slash. The finished job has left deep masses of brush on relatively small areas, usually with an adequate stand of saplings rising above the debris. The brush forms a mulch which is expected to favor growth of the young pines. Apprehension is felt lest the saplings be attacked by Ips broods which are due to emerge from the slash in June.

The main utilization roads, aggregating about 4-1/2 miles in length, will serve as firebreaks and to that end the slash is being removed to a distance of 20 feet on each side. The purpose is not to create barriers which fires cannot pass but to provide lines of defense.

Admittedly, the fire danger has been increased by the addition of logging debris in 1939. But it was already great because of old logging slash, tall bunchgrass, and sapling thickets which provide a large amount of fuel in themselves. Piling and burning the 1939 slash would have destroyed much reproduction without adequately reducing the fire danger. Wherever fire is permitted to run, it will kill pine reproduction. Reliance must be placed on the national forest protective organization to hold fires to a minimum size.

Table 8.- Volume per acre cut and left by different methods of cutting, Sample Plot S3, 456 acres, 1939.

D.B.H. class	Before cutting: No. trees	Before cutting: Volume b.m.	Cut: No. trees	Cut: Volume b.m.	Left: No. trees	Left: Volume b.m.
Inches		Feet		Feet		Feet
Method 1. Favoring Dominants.						
12-14	1.73	104	0.63	38	1.10	66
15-17	2.07	263	0.76	94	1.31	169
18-20	2.08	495	0.83	202	1.25	293
21-23	1.63	645	0.68	268	0.95	377
24-26	1.55	913	0.72	430	0.83	483
27-29	1.14	981	0.65	566	0.49	415
30-32	0.71	818	0.42	494	0.29	324
33-35	0.33	508	0.29	448	0.04	60
36-38	0.14	272	0.13	248	0.01	24
39-41	0.07	158	0.07	158		
Totals	11.45	5157	5.18	2946	6.27	2211
Percent			45.2	57.1	54.8	42.9
Method 2. Favoring Subordinates						
12-14	2.70	159	0.80	48	1.90	111
15-17	2.80	361	1.01	133	1.79	228
18-20	2.62	614	1.27	299	1.35	315
21-23	2.71	1082	1.42	568	1.29	514
24-26	2.48	1465	1.40	829	1.08	636
27-29	1.53	1287	0.94	797	0.59	490
30-32	0.71	837	0.52	621	0.19	216
33-35	0.23	346	0.18	263	0.05	83
36-38	0.14	271	0.11	219	0.03	52
39-41	0.03	78	0.03	78		
42-44	0.01	18	0.01	18		
Totals	15.96	6518	7.69	3873	8.27	2645
Percent			48.2	59.4	51.8	40.6
Method 3. Salvage Cutting						
12-14	2.10	122	0.32	20	1.78	102
15-17	2.09	269	0.41	53	1.68	216
18-20	2.18	523	0.52	127	1.66	396
21-23	2.64	1049	0.68	272	1.96	777
24-26	2.18	1284	0.65	383	1.53	901
27-29	1.39	1175	0.45	382	0.94	793
30-32	0.70	809	0.34	394	0.36	415
33-35	0.28	429	0.16	240	0.12	189
36-38	0.14	274	0.07	144	0.07	130
39-41	0.05	118	0.04	88	0.01	30
42-44	0.02	54	0.01	36	0.01	18
45-47	0.01	21	0.01	21		
Totals	13.78	6127	3.66	2160	10.12	3967
Percent			26.6	35.3	73.4	64.7

Prediction of Yields

Several methods have been applied: (1) Lexen's growth chart[5] which correlates gross increment with average diameter and volume of residual stand; (2) an earlier yield table by Lexen which correlates net increment with volume of residual stand, disregarding average diameter; and (3) a percentage method which simply applies the known net increment percent during a given period after the first cut during a corresponding period after the second cut. Methods (1) and (2) were checked by applying them to the stand left in the first cut and comparing with increment obtained from actual records of growth and mortality. Since the growth chart in (1) covers only 20 years, comparisons are limited to that period. In this check, method (1), using average d.b.h. of 18.4 inches, gave a 20-year gross increment of 1,800 board feet per acre, which, after deducting the known mortality of 20 feet per acre per year, is reduced to a net increment of 1,400 feet. Since the growth chart does not take into account "new" trees which grew into the 10-inch class after the records began, the above figure would be expected to be too low; but inasmuch as a complete record of "new" trees is not available, this factor cannot be taken into account. Methods (2) and (3) automatically include both new trees and mortality. Method (2) gives a net increment of 1,765 board feet. The actual net increment was 1,816 board feet. Method (3) obviously gives this same figure. As between methods (1) and (2), the latter appears to be the more applicable in this case. Method (3) has the advantage of being based entirely on the records of this area; one shortcoming is that it does not take into account the well known fact that as residual volume declines increment percent usually rises. This would have the effect of making predictions ultraconservative when applied to the lower residual volume after the second cut. A slight discrepancy arises from the fact that method (1) includes all trees above 9.5 inches d.b.h., whereas methods (2) and (3) go only down to 11.5 inches.

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[5] Lexen, Bert. Growth after cutting in ponderosa pine. Research Note No. 51, Southwestern Forest and Range Experiment Station. Also, Growth following partial cutting in ponderosa pine. Jour. Forestry 37:943-46. 1939.

Total volume in 20 and 30 years.

Table 9.- Yield prediction by two methods, based on a residual volume of 2,968 board feet per acre after the second cutting.

Method of prediction	Net increment per acre		Total volume per acre	
	20 years	30 years	20 years	30 years
	Ft.b.m.	Ft.b.m.	Ft.b.m.	Ft.b.m.
2	1,506	2,219	4,474	5,187
3[a]	1,531	2,048	4,499	5,016

[a] Net annual increment 20 years 2.58 percent;
30 years 2.30 percent.

Volume suitable for cutting in 1969.

Of more immediate interest is the volume in sizes suitable for cutting 30 years from now. It is estimated that the cut at that time will take nearly all trees then 28 inches d.b.h. or over. Assuming an average diameter growth of 4 inches in the next 30 years, this would theoretically include all the timber now above the 23-inch class. Actually, however, some trees will grow only 3 inches while others will grow as much as 6 inches, and therefore cutting to a minimum limit of 28 inches in 1969 would not include all trees now in the 24-inch class, but would include some below this class. In practice, cutting will not adhere to any arbitrary diameter limit, and therefore the present 24-inch class is to be regarded as only an approximate dividing line.

Methods (1) and (2), for obvious reasons, do not lend themselves to prediction of the increment of a portion of the stand. Method (3) is here applied to the entire area and to the three cutting divisions separately.

Table 10.- Prediction of volume per acre in 1969 of trees now over 23 inches in diameter.

Cutting area	Reserve volume above 23 inches	Increment percent in 30 years	Volume in 1969
	Ft.b.m.	Percent	Ft.b.m.
Entire area	1,772	139.6	4,246
Favoring Dominants	1,306	139.6	3,129
Favoring Subordinates	1,477	139.6	3,539
Salvage Cutting	2,476	139.6	5,952

Several factors may affect the above estimates. A possible source of error lies in the assumption that the advance from lower diameters into the 24-inch class proceeds at the same rate as during the first 30 years, which may or may not be true. As pointed out elsewhere, the residual volume will be reduced somewhat by elimination of worthless trees. There is an element of conservatism in the fact that the black-jack groups have on the whole been opened up more than in the first cutting, and the proportion of large yellow pines has decreased. Mistletoe infection has been more drastically eradicated than in the first cut, which should tend to lower the mortality and help to maintain normal growth.

Whether the indicated volumes are actually removed in 1969 depends on many circumstances, both silvicultural and economic. In addition to these volumes, there will be a growing stock of from 4 to 6 trees per acre in diameter classes now between 11 and 24 inches. A heavy cutting may be desirable in order to eradicate mistletoe, or to favor rising pole stands. On the other hand, it may be considered desirable to hold a large portion of the old stand to increase the yield in 1999, assuming continuance of the 30-year cycle. The salvage cutting unit will undoubtedly call for a heavy removal in 1969. Calculated yields will be reduced by about 10 percent for defect.

Prediction of volumes more than 30 years hence is rather speculative. Nevertheless, on the basis of present numbers in diameter classes between 11 and 24 inches, all three divisions may be expected to yield substantial cuts in 1999 and leave some trees to form the nucleus of a cut 30 years later, or 2029. The few poles now 5 to 10 inches d.b.h. will be a factor at that time. The fifth cutting, in 2029, will remove the last of the timber now over 100 years old and begin taking the largest of the younger generation.

It is sufficient for the present to point out that, barring unforeseen disasters, volumes approximately equal to the 1939 cut will be available in 1969 and 1999. After 1999, the situation involves more uncertainties. There can be little doubt that the growing stock will be strongly reinforced within another 60 years by extensive stands of young trees, but the time is too far off to warrant prediction of diameters and volumes. An indication is furnished by records showing that 173 saplings which entered the 4-inch class in 1929 grew 3.22 inches the following decade, and 797 trees entering the 4-inch class in 1934 grew 2.02 inches during the following 5 years. No "new" trees were measured in 1939. The numbers now entering the 4-inch class are so great that it has been decided to postpone tagging until a diameter of 8 inches is reached, and then tag only the trees on representative plots or strips.

Improving Future Stands

The Older Generation.

Natural pruning has progressed well in the denser blackjack groups, particularly among subordinate stems. Where cutting is directed toward releasing such stems, high value increment may be expected. Supplementary pruning of the better stems clears them to a height of one log length. Such pruning, now in progress, is generally limited to trees which require not more than 10 minutes of one man's time.

Mistletoe may also be controlled to some extent by pruning. Experience on this area indicates that such operations are practical only when mistletoe is confined to the lower branches.

Unmerchantable trees above the pole stage were poisoned in 1938. A few additional trees of this class will be poisoned or cut. This will reduce slightly the remaining stand as given in tables 1 and 8. The effect will become noticeable mainly in diameter classes below 20 inches.

The Younger Generation.

Training young growth into the desired type of stands is the largest problem confronting silviculture in the Southwest. Although the reproduction on this area is generally regarded as even-aged, there is wide variation in size even within the 1919 age class, and there are a few noticeably larger stems dating back to 1914, 1910, or even earlier. After grazing and porcupine damage abated, these older individuals advanced faster than the 1919 class; they are now from 5 to 8 inches d.b.h.; unfortunately, there are only some 5 or 6 per acre. Given free rein, most of these dominants would become wolf trees; but by timely pruning they can be made into valuable, fast-growing trees capable of contributing substantially to the cut in 2029.

Sapling stands will be allowed to develop naturally except for pruning, improvement cutting, and mistletoe eradication. Thinning, as such, is seldom desirable even in the densest thickets, except where stems are so close that they would grow together at the base. Dominants now around 4 inches d.b.h. are numerous; they should be pruned before they pass the 6-inch diameter class. Two or three operations may be required to attain a clear length of 17 feet. These dominants will exercise an important function in training subordinate stems, and they will provide the harvest 120 years from now.

One may readily visualize dense young stands of the future developing in much the same manner as present blackjack groups, minus the wolf trees and other rough-boled individuals. There are already enough openings to perpetuate the pattern of even-aged groups, but future groups will be larger and closer together than those of the old stand. Variations in size and rate of growth will foster selective cutting, progressively removing the larger stems as they attain merchantable size and automatically releasing subordinates which have at least partially cleared their boles. If dominants in dense formation are kept pruned until the stand is 50 years old, few of them need be sacrificed and relatively little pruning of subordinates should be necessary. Here is one answer to the quality problem in the Southwest.

It does not require much imagination to visualize this forest 100 years hence. In contrast with the deficient, poorly distributed, partly overmature, mistletoe-infected, and generally low-value stand which characterized the second cutting cycle, the future forest is pictured as almost fully stocked with predominantly young and healthy trees of good timber form. Instead of a mean annual increment of 80 board feet per acre of low-grade logs in the first cutting cycle, the fifth cycle will have a growing stock capable of yielding 150 board feet of relatively high-grade logs. Estimates of both yield and quality assume intensive management, including stand improvement. Values will depend on many factors that cannot be discussed here; but, according to available standards, accessible lands of this class will yield higher monetary returns and higher public benefits under intensive management than is possible under the extensive management now in general practice on the national forests.